REPORT

ON THE

WATERS OF THE HUDSON RIVER,

TOGETHER WITH AN

ANALYSIS OF THE SAME,

MADE TO THE

WATER COMMISSIONERS

OF THE

CITY OF ALBANY,

BY

C. F. CHANDLER, PH.D.

JANUARY, 1885.

NEW YORK:
TROW'S PRINTING AND BOOKBINDING CO.,
201-213 EAST TWELFTH STREET.
1885.

With the compliments of

C. F. CHANDLER,

SCHOOL OF MINES,

Columbia College,

49TH STREET, COR. 4TH AVE., NEW YORK,

who will be greatly obliged for copies of Water Analyses and Pamphlets on Sanitary Subjects.

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REPORT.

NEW YORK, January 31, 1885.

To the Board of Water Commissioners of the City of Albany:

GENTLEMEN: In accordance with your request, I have made a careful study of the water of the Hudson River at Albany, with special reference to its present condition, and to the question whether it is still safe to rely upon it as a source of supply for the city of Albany.

As you are aware, I had the honor to be called upon to investigate this subject, by the Board of Water Commissioners in 1872, and my conclusions were embodied in the following paragraph at the end of the report which I made in that year:

"The most careful examination of the water has failed to reveal anything to sight, taste, smell, or analysis, which can be considered as throwing the slightest suspicion upon the purity of the water of the Hudson, or its fitness for supplying a perfectly wholesome beverage for the citizens of Albany. I am further confirmed in this opinion by the careful comparison of the river and its surroundings with the sources of supply in other cities in this country and Europe. I have no hesitation, therefore, in recommending it as a suitable and proper source of supply."

I understand you to ask me now whether anything has occurred during the past thirteen years to lead me to change my opinion as expressed in 1872; whether new methods of chemical analysis may not have been introduced which make it possible to discover contaminations which could not be recognized by the methods formerly employed; whether other methods of analysis, especially microscopic and culture experiments, may not reveal the presence of dangerous organisms which would escape every method of chemical analysis; whether the knowledge of zymotic diseases has not advanced to such a degree as to compel different conclusions; and finally, whether the test of experience in the city of Albany

has not demonstrated the danger of making use of this source of water supply.

I have carefully considered each of these questions and will briefly state the results.

I. CHEMICAL ANALYSIS.

In 1872, I made an analysis of a sample of the water taken from the river outside the pier opposite Quackenbush Street, on March 14th, by the methods then in use for such analyses. The following were the results :

The suspended impurities which rendered the water turbid, being temporary in character, were allowed to subside ; the clear water was then found to contain the following substances in one United States gallon of 231 cubic inches. An analysis of the Croton water was presented at the same time for comparison.

I. Analysis of the Water.

	Hudson River.	Croton River.
Chloride of sodium	0.361 grains.	0.402 grains.
Chloride of magnesium	0.157 "	....
Sulphate of potassa	0.076 "	0.179 "
Sulphate of soda	....	0.260 "
Sulphate of lime	0.980 "	0.158 "
Bicarbonate of lime, $CaH_2(CO_3)_2$	4.165 "	2.670 "
Bicarbonate of magnesia, $MgH_2(CO_3)_2$	1.397 "	1.913 "
Silica	0.408 "	0.621 "
Alumina and oxide of iron	0.070 "	a trace.
Organic and volatile matter	0.699 "	0.670 "
Total	8.313 grains.	6.873 grains.
Hardness	3.35°	2.51°

The above figures represented the compounds as they were believed to exist in solution in the water. It should be noticed that the Hudson River water compares very favorably with the Croton in purity, the total difference per gallon being only 1.54 grains.

It was clearly recognized at that time that the mineral constituents of a water, while they might be of importance in determining the value of a water for manufacturing or culinary purposes, are not, unless present in very unusual quantities, many times the amount contained in the Hudson

River water, of any significance in discussing the fitness of water for drinking purposes. It was well understood that the only constituents that could possibly produce disease were the organic constituents,—namely, those derived from sewage,—and it was well recognized that the method of distinguishing wholesome from unwholesome organic matter was not very accurate. I did not, therefore, at that time rely upon the analysis, but carefully discussed the waters of the Hudson River as compared to those of other large rivers which had been found to be entirely satisfactory for domestic purposes in other parts of the world, the discussion being based upon other considerations than chemical composition, namely, the drainage area, population, flow of stream, etc.

Since that time considerable progress has been made in the chemical analysis of waters, with special reference to the examination for sewage contamination. It has been found that where water has been contaminated with sewage it will exhibit, when tested by the new methods of analysis, the unchanged organic substances of the sewage, which can be recognized and estimated in quantity by distilling the water with permanganate of potash. This process converts the albuminoids of the sewage into ammonia, the amount of which can be determined with great accuracy. From this the amount of albuminoids in the water can be computed. It is further found that the sewage in the water is rapidly destroyed, and that the products of this destruction are ammonia salts, commonly spoken of as "free ammonia," and nitrates and nitrites. When, therefore, water has been recently contaminated by sewage, the amount of such contamination can now be determined with great accuracy by an analysis which shows the amount of free ammonia, albuminoid ammonia, nitrites, and nitrates, and as far as determining the extent to which the water is contaminated, this method is quite satisfactory.

I have carefully applied it to samples of the Hudson River water, having twice visited Albany for the purpose of observing the local surroundings of the river, and of procuring samples. I have been assisted in these analyses by Dr. Elwyn Waller, the Instructor in Analytical Chemistry in the School of Mines, who has been engaged in making similar analyses of waters in other localities for the State Board of Health. I

also procured from a friend in Troy a sample of the water of the river taken above Lansingburg, and a sample of the water drawn from a hydrant in Troy.

It will be noticed that samples were taken from the river at the inlet to the pumping station, both at high and low tide, on two different days, as well as from the Bleecker Reservoir and Tivoli Lake

The results of these analyses are presented in tabular form. Table II presents them expressed in grains per United States gallon of 231 cubic inches. Table III presents them in parts per 100,000, this being a European method of presenting such analyses. It will be noticed on inspecting the tables that two analyses have been made in several cases, as indicated by the numbers. Two demijohns of water were taken in each of those cases. The analyses marked 5*c*, 6*c*, 9*c*, and 10*c*, were made of the clear water in the demijohn after allowing the sediment to subside. The analyses marked 5*s*, 6*s*, 9*s*, and 10*s*, were made from the water of the duplicate demijohn, care being taken to first shake the demijohn in order to bring all the sediment into suspension, so that the analyses include the sediment in these four cases. The figures in the tables represent all the analyses that were made. The important columns are those which show the "chloride of sodium," the "nitrogen in nitrates and nitrites," the "free ammonia," and the "albuminoid ammonia," these being the figures which represent the organic matter derived from all sources.

As chloride of sodium, or common salt, is a substance which is freely used in all dwellings, it naturally finds its way into the drainage, and the amount of this substance in water is found to indicate, to some extent, the variations in the quality, though it is of little use in comparing samples of water from different localities.

To facilitate comparisons, Tables IV and V have been prepared. They exhibit the results of these analyses shown as whole numbers in ten-thousandths of a grain in one U. S. gallon of 231 cubic inches, and in parts in one thousand million.

For further comparison tables of analyses of American and Foreign waters are presented.

INTERPRETATION OF THE RESULTS.

It will be seen from a careful comparison of the analyses of the Albany and Troy waters that the water at Albany actually contains a smaller quantity of albuminoids than the water above Troy, in spite of the fact that there is undoubtedly some addition of matter to the river in its passage past Troy, while the products of the destruction of organic matter, that is, free ammonia and nitrates and nitrites, have increased. This is entirely in keeping with the theory of spontaneous purification. Running streams may receive moderate quantities of organic matter and lose the same by chemical changes which take place in the water. In my report in 1872 I devoted considerable space to the subject of spontaneous purification, and quoted largely from the best European authorities to support the opinion which I gave, that such spontaneous purification takes place. This position was not satisfactory to those citizens of Albany, who had made up their minds beforehand that the Hudson River water must be largely impure, and the possibility of such purification was seriously questioned in the discussions which ensued.

This process has been thoroughly investigated in the past few years, and it is now admitted by all writers upon the subject. It is hardly necessary, therefore, to present any further evidence upon this point. The writings of Frankland, Tidy, Warington, Poleck, and many others, are very explicit upon the subject. Lest there may possibly exist unbelievers in this process I venture to insert the following quotations:

"It must, nevertheless, be borne in mind that by the constant exposure of fresh surfaces of polluted water to the action of the atmosphere, which is accomplished in a running stream, the organic matter is oxidized, and may thus be eventually converted into products which are perfectly harmless; in other words, a river is competent to effect its own purification unless overtaxed with pollution" (Huxley, 1878).

"The decay of organic matter is the joint work of a number of independent organisms of different functions, the action of one class following that of another, and carrying the process through a further stage. We are too imperfectly ac-

II. Analyses of the Mohawk and Hudson River Waters.

All Results are Expressed in Grains per United States Gallon of 231 Cubic Inches.

Number.	Description of Sample.	Date when taken.	Time when drawn.	Appearance in two-foot tube.	Odor when heated to 100° Fahrenheit.	Chlorine in chlorides.	Equivalent to sodium chloride.	Phosphates.	Nitrites.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Oxygen absorbed at 80° Fahr.		Hardness equivalent to carbonate of lime.		Organic and volatile matter.	Mineral matter.	Total solids dried at 230° Fahrenheit.
													In 15 minutes.	In 4 hours.	Before boiling.	After boiling.			
1	Mohawk River, above Diamond Woollen Mills	1884. Dec. 5	...	Turbid, greenish yellow	Faint, aromatic	0.133	0.216	......	......	0.0411	0.0026	0.0043	0.1208	0.2160	3.988	3.988	0.991	5.249	6.240
2	Hudson River, above Lansingburg	Nov. 12	...	Faintly turbid, light greenish yellow	Faint, vegetable	0.136	0.216	......	......	0.0144	......	0.0087	0.1569	0.2420	2.227	2.227	1.283	3.382	4.065
3	Troy Hydrant	" 12	...	Faintly turbid, light greenish yellow	Faint, vegetable	0.136	0.216	......	......	0.0166	0.0009	0.0089	0.1604	0.2333	2.623	2.337	1.516	3.791	5.307
4	Hudson River, at Maple Island	Dec. 6	...	Faintly turbid, greenish yellow	Faint, marshy	0.097	0.154	......	......	0.0358	0.0008	0.0048	0.1649	0.2391	2.944	2.822	1.400	3.091	4.491
5c	Hudson River, at inlet	Nov. 1	High tide.	Clear, light yellow	Faint	0.192	0.309	......	......	0.0161	0.0037	0.0059	0.0974	0.1812	3.439	3.439	0.816	5.715	6.531
5s	Hudson River, at inlet	" 1	"	Faintly turbid, light yellow	Faint, stale	0.192	0.309	......	......	0.0154	0.0022	0.0083	0.1102	0.1994	3.637	3.637	2.916	4.199	7.115
6c	Hudson River, at inlet	" 1	Low tide.	Clear, brownish yellow	Faint	0.213	0.340	......	......	0.0275	0.0016	0.0078	0.1271	0.1854	3.637	3.549	1.050	5.365	6.415
6s	Hudson River, at inlet	" 1	"	Turbid, brownish yellow	Faint	0.213	0.340	......	......	0.0168	0.0029	0.0072	0.1283	0.2024	3.527	3.527	2.799	4.782	7.581
7	Hudson River, 50 ft. south of inlet	Dec. 4	High tide.	Slightly turbid, brownish yellow	Oily	0.153	0.216	......	......	0.0377	0.0031	0.0066	0.1463	0.2510	3.190	3.190	2.041	2.624	4.665
8	Hudson River, at inlet	" 4	Low tide.	Turbid, brownish yellow	Oily	0.107	0.170	......	......	0.0353	0.0037	0.0052	0.1300	0.2578	3.405	3.405	0.875	4.374	5.249
9c	Bleecker Reservoir	Nov. 1	...	Clear, faint yellow	......	0.198	0.315	......	......	0.0282	0.0030	0.0040	0.0881	0.1503	3.108	2.270	1.458	5.132	6.590
9s	Bleecker Reservoir	" 1	...	Turbid, faint yellow.	Faint, stale	0.198	0.315	......	......	0.0285	0.0027	0.0059	0.1023	0.1761	3.846	3.846	3.324	3.966	7.290
10c	Tivoli Lake	" 6	...	Faint milkness	Faint, stale	0.486	0.773	Doubtful.	Trace.	0.0296	0.0107	0.0047	0.0455	0.1184	4.122	2.513	1.166	6.998	8.164
10s	Tivoli Lake	" 6	...	Whitish, milky	Faint, stale	0.486	0.773	Faint trace.	Trace.	0.0356	0.0115	0.0163	0.0700	0.1053	4.321	3.196	3.499	6.415	9.914
11	Tivoli Lake	Dec. 4	...	Turbid, greenish	Faint, marshy.	0.563	0.896	Faint trace.	Faint trace.	0.0778	0.0220	0.0069	0.0627	0.1027	4.938	4.938	1.866	6.065	7.931

III. Analyses of the Mohawk and Hudson River Waters.

All Results are Expressed in Parts per 100,000.

Number.	Description of Sample.	Date when taken.	Time when drawn.	Appearance in two-foot tube.	Odor when heated to 100° Fahrenheit.	Chlorine in chlorides.	Equivalent to sodium chloride.	Phosphates.	Nitrites.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Oxygen absorbed at 80° Fahr. In 15 minutes.	Oxygen absorbed at 80° Fahr. In 4 hours.	Hardness equivalent to carbonate of lime. Before boiling.	Hardness equivalent to carbonate of lime. After boiling.	Organic and volatile matter.	Mineral matter.	Total solids dried at 230° Fahrenheit.
1	Mohawk River, above Diamond Woollen Mills	1884. Dec. 5	......	Turbid, greenish yellow	Faint, aromatic	0.233	0.371	......	......	0.0705	0.0044	0.0074	0.2071	0.3704	6.838	6.838	1.70	9.00	10.70
2	Hudson River, above Lansingburg	Nov. 12	......	Faintly turbid, light greenish yellow	Faint, vegetable	0.233	0.371	......	......	0.0247	......	0.0150	0.2691	0.4150	3.818	3.818	2.20	5.80	8.00
3	Troy Hydrant	" 12	......	Faintly turbid, light greenish yellow	Faint, vegetable	0.233	0.371	......	......	0.0284	0.0015	0.0151	0.2756	0.4000	4.498	4.498	2.60	6.50	9.00
4	Hudson River, at Maple Island	Dec. 6	......	Faintly turbid, greenish yellow	Faint, marshy.	0.167	0.265	......	......	0.0614	0.0014	0.0082	0.2827	0.4100	5.049	4.839	2.40	5.30	7.70
5c	Hudson River, at inlet	Nov. 1	High tide.	Clear, light yellow	Faint	0.333	0.530	......	......	0.0277	0.0064	0.0102	0.1670	0.3111	5.897	5.897	1.40	9.80	11.20
5s	Hudson River, at inlet	" 1	"	Faintly turbid, light yellow	Faint, stale	0.333	0.530	......	......	0.0265	0.0038	0.0142	0.1890	0.3422	6.237	6.237	5.00	7.20	12.20
6c	Hudson River, at inlet	" 1	Low tide.	Clear, brownish yellow	Faint	0.366	0.583	......	......	0.0471	0.0028	0.0124	0.2180	0.3180	6.237	6.086	1.80	9.20	11.00
6s	Hudson River, at inlet	" 1	"	Turbid, brownish yellow.	Faint	0.366	0.583	......	......	0.0288	0.0050	0.0124	0.2200	0.3470	6.048	6.048	4.80	8.20	13.00
7	Hudson River, 50 ft. south of inlet	Dec. 4	High tide.	Slightly turbid, brownish yellow	Oily	0.233	0.371	......	......	0.0647	0.0054	0.0114	0.2509	0.4310	5.470	5.470	3.50	4.50	8.00
8	Hudson River, at inlet	" 4	Low tide.	Turbid, brownish yellow	Oily	0.183	0.291	......	......	0.0606	0.0064	0.0090	0.2220	0.4420	5.838	5.858	1.50	7.50	9.00
9c	Bleecker Reservoir	Nov. 1	......	Clear, faint yellow	......	0.340	0.541	......	......	0.0484	0.0052	0.0068	0.1511	0.2578	5.330	3.893	2.50	8.80	11.30
9s	Bleecker Reservoir	" 1	......	Turbid, faint yellow.	Faint, stale	0.340	0.541	......	......	0.0489	0.0046	0.0102	0.1755	0.3020	6.577	6.577	5.70	6.80	12.50
10c	Tivoli Lake	" 6	......	Faint milkiness	Faint, stale	0.833	1.325	Faint trace.	Faint trace.	0.0507	0.0184	0.0080	0.0780	0.2030	7.069	4.309	2.00	12.00	14.00
10s	Tivoli Lake	" 6	......	Whitish, milky	Faint, stale	0.833	1.325	Faint trace.	Faint trace.	0.0611	0.0198	0.0280	0.1200	0.1852	7.469	5.481	6.00	11.00	17.00
11	Tivoli Lake	Dec. 4	......	Turbid, greenish	Faint, marshy.	0.966	1.537	Faint trace.	Faint trace.	0.1334	0.0380	0.0118	0.1075	0.1762	8.468	8.468	3.20	10.40	13.60

IV. Results of the Analyses

Expressed in Ten-thousandths of a Grain per U. S. Gallon of 231 Cubic Inches.

Number.	Locality.	Sodium chloride.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.
1	Mohawk River, above Diamond Woollen Mills ..	2,160	411	26	43
2	Hudson River, above Lansingburg	2,160	144	0	87
3	Troy Hydrant....................................	2,160	166	9	89
4	Hudson River, at Maple Island	1,540	358	8	48
	Hudson River, at Albany—				
5c	At inlet, high tide..........................	3,090	161	37	59
5s	At inlet, "	3,090	154	22	83
6c	At inlet, low tide..	3,400	275	16	78
6s	At inlet, "	3,400	168	29	72
7	At inlet, high tide..........................	2,160	377	31	66
8	At inlet, low tide..............	1,700	353	37	52
9c	Bleecker Reservoir................................	3,150	282	30	40
9s	" "	3,150	285	27	59
	Average for river water used at Albany	2,892	257	28	62
10c	Tivoli Lake	7,730	296	107	47
10s	"	7,730	356	115	163
11	"	8,960	778	220	69
	Average for Tivoli Lake	8,140	477	147	93

V. Results of the Analyses

Expressed in Parts in One Thousand Million.

Number.	Locality.	Sodium chloride.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.
1	Mohawk River, above Diamond Woollen Mills	3,710	705	44	74
2	Hudson River, above Lansingburg	3,710	247	0	150
3	Troy Hydrant..........	3,710	284	15	151
4	Hudson River, at Maple Island	2,650	614	14	82
	Hudson River, at Albany—				
5c	At inlet, high tide...........................	5,300	277	64	102
5s	At inlet, "	5,300	265	38	142
6c	At inlet, low tide............................	5,830	471	28	134
6s	At inlet, "	5,830	288	50	124
7	At inlet, high tide............	3,710	647	54	114
8	At inlet, low tide............................	2,910	606	64	90
9c	Bleecker Reservoir................................	5,410	484	52	68
9s	" "	5,410	489	46	102
	Average for river water used at Albany	4,962	441	49	109
10c	Tivoli Lake	13,250	507	184	80
10s	"	13,250	611	198	280
11	"	15,370	1,334	380	118
	Average for Tivoli Lake................	13,957	817	254	159

VI. American Waters.

The Results are Expressed in Ten-Thousandths of a Grain per U. S. Gallon of 231 Cubic Inches.

Number.	Locality.	Date.	Chloride of sodium.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Analyst.
	New York City—						
1	Croton River	Dec., 1884	3,090	379	5	52	E. Waller.
	Boston, Mass.—						
2	Cochituate Lake ...... max.	....	....	....	39	113	W. R. Nichols.
3	" " ...... min.	....	....	....	3	57	" "
4	" "	Nov., 1881	....	....	9	67	Ira Remsen.
5	Farm Pond ...... max.	....	...	....	19	262	" "
6	" " ...... min.	....	....	....	0	158	" "
7	Sudbury River ...... max.	....	5,773	....	25	176	E. S. Wood.
8	" " ...... min.	....	2,020	....	3	49	" "
	Springfield, Mass.—						
9	Broad Brook	Jan., 1876	2,429	....	58	75	C. O. Thompson.
10	" "	" "	1,943	....	38	74	W. R. Nichols.
11	" "	Apr., 1873	4,275	....	11	70	C. O. Thompson.
	Lowell, Mass.—						
12	Merrimac River *	Sep., 1873	1,359	....	29	66	W. R. Nichols.
13	" " †	" "	1,942	....	25	64	" "
14	" " ‡	" "	1,749	....	18	74	" "
	Worcester, Mass.—						
15	Blackstone River §	—, 1873	15.550	....	2.157	239	" "
16	" " ‖	—, "	6,607	....	145	128	" "
17	" " ¶	—, "	5,053	....	29	87	" "
	Taunton, Mass.—						
18	Taunton River	Aug., 1877	....	....	29	123	" "
	New London, Conn.—						
19	Lake Konomac	Dec., 1879	....	....	29	93	" "
	Plymouth, Mass.—						
20	South Pond	June, 1877	....	....	46	99	" "
	Grand Rapids, Mich.—						
21	Grand River	Nov., 1879	....	...	7	103	Hugo Thum.
	Toronto, Canada—						
22	Lake Ontario	Nov., 1881	3,267	134	11	63	W. H. Ellis.
	Philadelphia, Pa.—						
23	Schuylkill River	Jan., 1880	3,304	....	17	145	G. F. Barker.
24	" "	June, 1880	2.916	886	5	104	A. R. Leeds.
25	" "	Nov., 1881	9,135	356	0	15	H. Leffmann.
26	Delaware River	" "	18,175	...	46	116	" "
	Portsmouth, Va.—						
27	Dismal Swamp	Nov., 1884	896	469	13	457	E. Waller.
	Cincinnati, O.—						
28	Ohio River	Nov., 1880	12,798	....	29	92	C. R. Stuntz.
	Nashville, Tenn.—						
29	Cumberland River	Oct., 1876	2,887	665	0	23	U. T. Lupton
	St. Louis, Mo.—						
30	Missouri River	Jan., 1878	....	....	7	122	G. W. Riggs.
31	Mississippi River	" "	....	....	15	519	" "
	Jersey City, N. J.—						
32	Passaic River	Jan., 1880	2.165	997	29	219	A. R. Leeds.
	Watertown, N. Y.—						
33	Black River	June, 1881	509	84	24	38	E. Waller.
	Yonkers, N. Y.—						
34	Grassy Spring River	Feb., 1875	3,175	....	32	54	W. R. Nichols.
	Hudson, N. Y.—						
35	Hudson River	Nov., 1877	....	....	34	88	" "
36	" "	Dec., 1877	2,886	....	29	88	" "
37	" "	Jan., 1878	3,175	....	71	77	" "
	Poughkeepsie, N. Y.—						
38	Hudson River	Nov. 13, '77	3,081	....	63	115	" "
39	" "	Nov. 19, '77	3,081	....	60	91	" "
	Brooklyn, N. Y.—						
40	Ridgewood	May, 1884	11,643	....	9	17	E. H. Bartley.
	Syracuse, N. Y.—						
41	Oneida Lake	—, 1884	5,759	....	13	59	F. Engelhardt.
42	Tully Lake	—, "	5,279	...	18	126	" "

* Above Lowell.
† Below Lowell, above Lawrence.
‡ Below Lawrence.
§ Below Worcester.
‖ Five miles below Worcester.
¶ Twenty miles below Worcester.

VII. American Waters.

The Results are Expressed in Parts in One Thousand Million.

Number.	Locality.	Date.	Chloride of sodium.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Analyst.
	New York City—						
1	Croton River	Dec., 1884	5,300	651	10	90	E. Waller.
	Boston, Mass.—						
2	Cochituate Lake......max.	....	....	....	67	195	W. R. Nichols.
3	" " ......min.	....	....	....	5	99	" "
4	" "	Nov., 1881	....	....	16	116	Ira Remsen.
5	Farm Pond........ ..max.	....	....	....	34	450	" "
6	" " ....min.	....	....	....	0	272	" "
7	Sudbury River.......max.	....	9,900	....	43	302	E. S. Wood.
8	" " ....min.	....	3,465	...	5	84	" "
	Springfield, Mass.—						
9	Broad Brook..	Jan., 1876	4,165	....	100	130	C. O. Thompson.
10	" "	" "	3,333	....	66	128	W. R. Nichols.
11	" "	April, 1873	7,330	....	26	120	C. O. Thompson.
	Lowell, Mass.—						
12	Merrimac River *	Sep., 1873	2,330	....	47	114	W. R. Nichols.
13	" " †	" "	3,330	....	44	110	" "
14	" " ‡	" "	3,000	....	31	127	" "
	Worcester, Mass.—						
15	Blackstone River §	—, 1873	26,665	....	3,700	410	" "
16	" " ‖	—, "	11,320	....	250	220	" "
17	" " ¶	—, "	8,665	...	50	150	" "
	Taunton, Mass.—						
18	Taunton River............	Aug., 1877	....	....	51	211	" "
	New London, Conn.—						
19	Lake Konomac............	Dec., 1879	....	....	50	160	" "
	Plymouth, Mass.—						
20	South Pond	June, 1877	....	....	80	170	" "
	Grand Rapids, Mich.—						
21	Grand River......	Nov., 1879	....	....	12	178	Hugo Thum.
	Toronto, Canada—						
22	Lake Ontario.............	Nov., 1881	5,500	230	19	109	W. H. Ellis.
	Philadelphia, Pa.—						
23	Schuylkill River	Jan., 1880	5,665	....	30	250	G. F. Barker.
24	" "	June, 1880	5,000	1,520	10	180	A. R. Leeds.
25	" "	Nov., 1881	15,665	610	0	26	H. Leffmann.
26	Delaware River...........	" "	31,165	....	80	200	" "
	Portsmouth, Va.—						
27	Dismal Swamp	Nov., 1884	1,537	805	23	751	E. Waller.
	Cincinnati, O.—						
28	Ohio River	Nov., 1880	21,945	....	50	156	C. R. Stuntz.
	Nashville, Tenn.—						
29	Cumberland River...... .	Oct., 1876	4,950	1,140	0	40	N. T. Lupton.
	St. Louis, Mo.—						
30	Missouri River...........	Jan., 1878	...	...	13	210	G. W. Riggs.
31	Mississippi River....	" "	....	....	26	890	" "
	Jersey City, N. J.—						
32	Passaic River.............	June, 1880	3,712	1,710	50	377	A. R. Leeds.
	Watertown, N. Y.—						
33	Black River	June, 1881	874	145	24	66	E. Waller.
	Yonkers, N. Y.—						
34	Grassy Spring River	Feb., 1875	5,445	....	55	93	W. R. Nichols.
	Hudson, N. Y.—						
35	Hudson River	Nov., 1877	....	....	59	152	" "
36	" "	Dec., 1877	4,950	....	51	152	" "
37	" "	Jan., 1878	5,445	....	123	133	" "
	Poughkeepsie, N. Y.—						
38	Hudson River	Nov. 13, '77	5,283	....	109	197	" "
39	" "	Nov. 19, '77	5,283	....	104	157	" "
	Brooklyn, N. Y.—						
40	Ridgewood	May, 1884	19,965	....	16	30	E. H. Bartley.
	Syracuse, N. Y.—						
41	Oneida Lake.........	—, 1884	9,876	....	22	102	F. Engelhardt.
42	Tully Lake	—, "	9,053	....	32	216	" "

* Above Lowell.

† Below Lowell, above Lawrence.

‡ Below Lawrence.

§ Below Worcester.

‖ Five miles below Worcester.

¶ Twenty miles below Worcester.

VIII. Waters of Great Britain and Ireland.

The Results are Expressed in Ten-thousandths of a Grain per U. S. Gallon of 231 *Cubic Inches.*

Number.	Locality.	Date.	Chloride of sodium.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Analyst.
	London, River Thames—						
1	Chelsea Company	March, 1883	13,471	1,248	35	35	Chloride of sodium and nitrogen in nitrates, etc., by E. Frankland. Free and albuminoid ammonia, by J. A. Wanklyn and W. J. Cooper.
2	West Middlesex Company	" "	13,471	1,539	23	41	
3	Southwark and Vauxhall Company	" "	14,434	1,919	35	47	
4	Grand Junction Company	" "	14,434	1,802	23	23	
5	Lambeth Company	" "	15,396	2,298	23	35	
	London, River Lea—						
6	New River Company	" "	15,396	2,187	12	23	
7	East London Company	" "	16,358	1,866	12	29	
8	Exeter, River Exe	Nov., 1881	11,547	1,825	15	26	F. P. Perkins.
9	Reading, River Kennet	" "	11,643	624	4	35	J. Shea.
10	Worcester, Rivers Severn and Vyrnwy	May, "	42,627	624	0	41	H. Swete.
11	King's Lynn, River Gaywood	Nov., "	21,843	2,682	18	70	W. Johnstone.
12	Plymouth, peat bogs	— "	11,643	3,330	8	38	R. Oxland.
13	Coatham, River Tees	Dec., 1877	7,794	373	68	58	G. W. Wigner.
14	Isle of Wight, River Yar	Sep., "	72,265	583	41	59	" "
15	Carnarvon, Quellyn Lake	" "	14,071	233	20	39	" "
16	Mayport, river water	Aug., "	10,672	466	27	59	" "
17	Whitehaven, Ennerdale Lake	" "	7,814	236	30	20	" "
18	Portmadoc, lake water	Sep., "	13,179	216	98	57	" "
19	Lynton, river water	Oct., "	13,646	117	34	56	" "
20	Llanfairfechan, river water	Nov., "	10,730	233	12	28	" "
21	Glasgow, Loch Katrine	April, 1876	not det.	150	6	50	Wm. Muir.
22	" " " *	March, 1882	6,062	47	0	47	E. J. Mills.
23	Dublin, Loch Vartry	Dec., 1881	13,568	trace	17	50	C. A. Cameron.

* Average for twelve months.

IX. Waters of Great Britain and Ireland.

The Results are Expressed in Parts in One Thousand Million.

Number.	Locality.	Date.	Chloride of sodium.	Nitrogen in nitrates and nitrites.	Free ammonia.	Albuminoid ammonia.	Analyst.
	London, River Thames—						
1	Chelsea Company	March, 1883	23,100	2,140	60	60	Chloride of sodium and nitrogen in nitrates, etc., by E. Frankland. Free and albuminoid ammonia, by J. A. Wanklyn and W. J. Cooper.
2	West Middlesex Company	" "	23,100	2,640	40	70	
3	Southwark and Vauxhall Company	" "	24,750	3,290	60	80	
4	Grand Junction Company	" "	24,750	3,090	40	40	
5	Lambeth Company	" "	26,400	3,940	40	60	
	London, River Lea—						
6	New River Company	" "	26,400	3,750	20	40	
7	East London Company	" "	28,050	3,200	20	50	
8	Exeter, River Exe	Nov., 1881	19,800	3,130	26	44	F. P. Perkins.
9	Reading, River Kennet	" "	19,965	1,070	7	60	J. Shea.
10	Worcester, Rivers Severn and Vyrnwy	May, "	73,095	1,070	0	70	H. Swete.
11	King's Lynn, River Gaywood	Nov., "	37,455	4,600	31	120	W. Johnstone.
12	Plymouth, peat bogs	— "	17,300	657	12	197	R. Oxland.
13	Coatham, River Tees	Dec., 1877	13,365	640	117	100	G. W. Wigner.
14	Isle of Wight, River Yar	Sep., "	123,915	1,000	71	101	" "
15	Carnarvon, Quellyn Lake	" "	24,300	400	34	67	" "
16	Mayport, river water	Aug., "	18,300	800	46	101	" "
17	Whitehaven, Ennerdale Lake	" "	13,400	404	51	35	" "
18	Portmadoc, lake water	Sep., "	22,600	371	169	97	" "
19	Lynton, river water	Oct., "	23,400	200	59	95	" "
20	Llanfairfechan, river water	Nov., "	18,400	400	20	48	" "
21	Glasgow, Loch Katrine	April, 1876	not det.	258	10	85	Wm. Muir.
22	" " " *	March, 1882	10,395	80	0	80	E. J. Mills.
23	Dublin, Loch Vartry	Dec., 1881	23,265	trace	29	86	C. A. Cameron.

* Average for twelve months.

quainted with the organisms effecting these changes, and their particular functions have been too little studied, for any accurate sketch of these processes to be given. In the first rank we must probably place the fungi, whose main function is apparently the rapid oxidation of carbon. Following these we have the innumerable army of bacteria, embracing many families of very similar physical structure, but endowed with very different chemical powers. One class of these bacteria attacks nitrogenous organic matter and liberates the nitrogen in the form of ammonia ; while another class of bacteria determines the conversion of carbonaceous organic matter and ammonia into simple organic bodies—carbonic and nitric acids. Lastly, we have the chlorophyll-bearing plants, which consume the carbonic acid, ammonia, and nitric acid produced by lower organisms, and are also capable of assimilating urea and other amide bodies, and a large number of inorganic ash constituents" (Warington, 1880).

"*En résumé*, the little beings which we have been considering have an important *rôle :* they cause the return of dead organic matter to the atmosphere and to water.

"Without them, organic matter, even exposed to the air, would not be destroyed, or would be transformed with extreme slowness, in consequence of a slow combustion produced by oxygen. With them, on the contrary, its destruction takes a rapid march and becomes complete. If, then, the equilibrium is maintained between living nature and dead nature, if the air has always the same composition, if the waters are always equally fertilizing, it is thanks to the infinitely minute agents of fermentation and putrefaction" (Magnin from Duclaux, 1878).

Hulwa, in his investigation of the River Oder, before it enters and after it has passed through the City of Breslau, found that in its progress through the city the river showed increased pollution, and at its exit was greatly polluted. A short distance down the river the effects of dilution became evident, the self-purification of the river by the combined action of the oxygen of the air and of the vegetable and animal life in the stream were very marked, and the impurities diminished so rapidly that at a few miles below the city the water was as pure as when it entered it. Hulwa thinks it a mistake to forbid the outflow of sewage into rivers, provided the outfall is below the city and the rapidity and volume of the stream are sufficient to carry the sewage to such a dis-

tance as will allow the operation of natural causes of purification (1884).

The action of air in effecting, directly or indirectly, the purification of water has been practically tested within the last year or two, in Hoboken and Philadelphia, where air has been systematically pumped into the water for the purpose of hastening the operation.

A further comparison of the Hudson River water at Albany with the chief waters used in America and England for city supplies, demonstrates the fact that the Hudson River water does not contain any excessive quantity of organic matters, and the application of these new methods of analysis confirms the opinion which I originally reached with regard to this water.

In a recent report of the Committee on Drainage, Sewage, and Topography of the State Board of Health, the statement is made that "the experience of the past ten years has clearly demonstrated that the chemical test cannot detect the specific poisons of zymotic diseases, and therefore the results of chemical analysis of the water of the Hudson River are no proof as to its safety for drinking purposes." This is no doubt the opinion of the Committee, but it is not the opinion of those persons who have had considerable experience in the examination of waters for sanitary purposes. I do not mean to say that chemical tests will detect the specific poisons of zymotic diseases in water. For that matter there is no method of investigation yet proposed which can accomplish this, except the actual production of the diseases, and no one has ever found in a river-water the specific poison of any zymotic disease. Dr. Koch thinks he observed the cholera bacillus in a water-tank at Calcutta in which persons suffering from cholera bathed and washed their clothes, and this is the only case in which any reliable authority has ever claimed to have found disease-germs in water of any kind.

In 1880, Dr. Tidy, of London, one of the best authorities on the subject of water examination, made the statement that "in all well-proved cases of outbreaks of disease resulting from the use of drinking-water, such water would have been unhesitatingly condemned on analysis by the chemist."

The Committee of the State Board of Health attempts to sustain its condemnation of chemical analysis by reference

to the epidemic of typhoid and typho-malarial fever in Bath, Steuben County, during the past year. In this case there is no evidence that the disease originated with the well-water. The printed analysis shows further that the water was very impure. It contains 37.6 parts in 100,000 of total impurities, while the quantity contained in the Hudson River water at Albany averages only about 10 parts in 100,000. This well-water further shows the presence of 9,900 parts of nitrogen derived from nitrates and nitrites in one thousand million parts of water, which is an enormous quantity. It should further be remembered that well-waters cannot be considered upon the same basis as river waters. The well contains a small quantity of water, which is not in motion, and which is not brought freely into contact with the air. Moreover, well-waters are very variable in composition. They are liable to temporary defilement, so that while at one time a well-water may fail to disclose any alarming peculiarities to chemical analysis, it may at a later period, owing to a change in the condition of the ground-water in its neighborhood, or to some accidental pollution, become charged with offensive matter. All chemists realize the fact that it is never safe to decide the condition of a well from a single analysis of the water, as no matter how pure the water may prove to be by analysis on any particular occasion, there is no certainty that this condition of purity will be maintained for any length of time. The river, on the other hand, is not subject to sudden variations in the quality of its waters. The conditions that surround it are pretty nearly uniform from one end of the year to the other, the greatest extremes being those which result from high water and low water. The opinion of the Committee as to the value of chemical analysis, as far as it is based on the Bath outbreak, is without adequate foundation.

The slight turbidity or opalescence which is noticed at times in the water drawn from the hydrants at Albany, is due to the clay which is so abundant in the Hudson and Mohawk valleys, either as soft clay or as crumbling shales. It has been shown by Professor W. H. Brewer, that clay settles very slowly from pure waters.

It will be noticed that the analyses of the water from Tivoli Lake, show a much larger amount of sodium chloride, nitrates, and of free and albuminoid ammonia. I did not visit

the lake, but I am satisfied from the analyses that drainage-water finds its way into this body of water.

II.—BIOLOGICAL ANALYSIS.

Great stress is now laid by many persons on what is called the biological analysis of water, and much has been published upon the subject within the last few years. It has been known for more than two hundred years, that minute organisms exist in water. They were discovered by Leeuwenhoek, in rain-water, in 1675, and have been studied with great interest ever since. Some are known to be animal in character, others vegetable. They have been carefully studied and classified, but while they were extremely interesting to the botanist and the zoölogist, they attracted very little attention from the chemist and the etiologist till quite recently. They first came into general notice in the study of fermentation, which had been supposed by many to be a purely chemical process, but which was finally traced to the agency of these minute organisms. It was found that there are a great many different kinds of fermentations, each of which is due to some one specific organism. The further study of these organisms led to the revival of the theory of spontaneous generation, and many elaborate investigations were made into their origin. Finally, it was found that most kinds of contagious and infectious disease, and many diseases that had never before been recognized as infectious, were due to peculiar micro-organisms.

These discoveries gave rise to what is known as the "germ theory" of disease. I have had special occasion to study this subject for various reasons in connection with my duties, and ten years ago I carefully examined the publications of the most active investigators of the subject in preparing an article on "Fermentation" for "Johnson's New Universal Cyclopedia." When it was proposed, therefore, to determine the sanitary quality of water by microscopic examination, either of the water itself, or of the culture-fluids or solid media planted with water, I was not taken by surprise, but was in a position to realize how much and how little might be expected from this method of examination.

Biological analysis has thus far been resorted to for the purpose of determining the number of germs or spores of micro-organisms contained in a given sample of water, and by counting them to decide on the relative value or safety of the water for domestic use. If these organisms, whether bacteria, algæ, or mould fungi, were only contained in polluted water, or if they were injurious to life, this method of examination would undoubtedly be extremely valuable, but as a matter of fact these organisms are found everywhere in nature. They have been shown by Dehérain, Maquenne, Koch, Miguel, Warington, and many others, to exist in all soils. They have been shown by everyone who has studied the subject to be constantly present in the atmosphere. The following quotation from the work of Cooke and Berkley on the fungi, expresses the universal opinion with regard to the occurrence of bacteria and other fungi in the air :

"Spores and other vegetable cells are constantly present in atmospheric dust, and usually occur in considerable numbers ; the majority of them are living and capable of growth and development. The amount of them present in the air appears to be independent of conditions of velocity and direction of wind, and their number is not diminished by moisture.

"No connection can be traced between the numbers of bacteria, spores, etc., present in the air, and the occurrence of diarrhoea, dysentery, cholera, ague, or dengue, nor between the presence or abundance of any special form or forms of cells and the prevalence of any of these diseases."

Bacteria are always present in water. Magnin and Sternberg say rain-water will always be found fertile in germs, and when it is collected with care it represents the bacterial flora of the atmosphere at the time of its fall. The following quotation is additional proof on this point :

"Water contains considerable quantities of bacteria and especially of germs. Their presence in atmospheric water is established by the experiments of Lemaire and Gratiolet, —and after them by more recent observers—by means of condensers filled with ice, and placed in the fields, and for comparison, in closed apartments. Rindfleisch has since expressed the opinion that the vapor of water does not contain spores or bacteria, and that telluric waters alone contain them ; but Billroth, Cohn, and others have proved that Rindfleisch was too positive in his statement.

"It is not surprising that telluric waters contain such a

quantity of bacteria, that their existence is admitted by all. The dust gathered upon the surface of stones, of leaves, of fruits, etc., shows upon microscopic examination an abundance of germs (Marie-Davy, Tissandier); the washing of these objects and of the soil by the rain, transports them into the rivers, and from the rivers to the sea, which contains considerable quantities of them.

"Thus, a drop of water from the Seine, according to Pasteur and Joubert, is always fecund, and may give birth to several species of bacteria. The distilled water of laboratories also contains germs, and these of so small a diameter that they pass through all filters. Cohn has proved that some are not arrested by a superposition of sixteen filters. The only waters which do not contain them are those drawn from the very source of a spring." (Magnin.)

It should further be noted that all kinds of food contain bacteria and other micro-organisms. Nothing is richer in bacilli than ordinary hay, from which they are never absent. Finally, I would call attention to the fact that human beings are never free from them. They occur in the body in life; they are constantly found in saliva, and the mucous membrane of the alimentary canal exhibits myriads of them in a state of activity. They are found upon the surface of the skin, in the bronchial passages, and in fact wherever air, water, or food are brought in contact with the body externally or internally. Pasteur recently read a paper, by Duclaux, before the French Academy of Sciences, in which he claimed that the presence of bacteria is indispensable to the germination of seeds and also to the digestion of food.

Cohn says:

"Bacteria belong to the most wide-spread of organisms; we may say they are omnipresent; they never fail either in air or water; they attach themselves to the surface of all firm bodies."

And according to Magnin:

"The bacteria are of all beings the most widely diffused. We meet them everywhere, in the air, in water, upon the surface of solid bodies, in the interior of plants and animals. If we expose a transparent liquid containing traces of organic substances, we find after a short time that it has become clouded, and the microscope shows us that it contains myriads of these beings."

Under these circumstances it would appear that counting the number of bacteria that will develop in gelatine, or in other culture media, on the addition of a sample of water, is not a very reliable method for determining the danger of water for domestic purposes, although some enthusiastic microscopists, carried away by their skill in raising bacteria in their microscopic gardens, have said that the days of chemical analysis of water supplies are numbered.

W. R. Nichols remarks in speaking of biological analysis :

"None of these methods have reached the subject of practical utility, and it must be left entirely with the specialists to interpret the results of their own observations."

Dr. Robert Angus Smith, who made a great many biological examinations of water with gelatine, in which he noted particularly the production of little spheres of transformed gelatine after the addition of water, remarks as follows :

"We must be careful in drawing conclusions as to the wholesomeness of the water tried ; the existence of spores of transformed gelatine caused by organisms is no proof that the water is unwholesome."

Dr. Frankland has also tested biological methods, and in one of his papers he states, speaking of such methods :

"My own experiments completely conform with Mr. Heich's observations, with two important exceptions, viz. : that, firstly, the fungi growths are not peculiar to water contaminated with sewage ; and secondly, the germs from which they originate are present in all water which has been even momentarily in contact with the air."

It is claimed by some of the biological experimenters that if a solid jelly, to which a little of the water has been added, becomes fluid in a short time, owing to the development of bacteria, it is proof positive that the water is contaminated with sewage, and that it is unwholesome.

I have applied this test to the waters from Albany, in comparison with Croton water, and with water from the Hackensack and the Passaic. In all cases the gelatine became fluid from the growth of organisms, which were readily seen under the microscope. At the same time I simply exposed to the air some jelly made from calves' feet, some clear

bouillon prepared from lean beef, and slices of white and Graham bread.

The calves'-foot jelly soon became fluid, the beef bouillon became turbid, and both became opaque and offensive. Under the microscope both were found to contain myriads of bacteria, some quiet, some in active motion. The slices of bread, which were covered with bell jars to prevent their becoming dry, were soon covered with a luxuriant growth of mycilium fungi or mould plants, white, green and yellow.

Now if the organisms in the gelatine, to which the samples of water were added, prove the water to have been contaminated with sewage, what can be said of the air of New York which filled the calves'-foot jelly and the bouillon with similar organisms, or covered the bread with the mould fungi?

Had the jelly, bouillon, or bread been exposed to the air of any other locality in the United States, the result would not have been different. The truth is, the germs of micro-organisms occur in all water and all air, and all that is necessary for their development is the proper soil, that is, organic matter, such as the jelly furnishes.

We have daily proof of this in the spontaneous fermentation of the juice of the grape in wine making, the transformation of cider into vinegar, the souring of beer and light wines, of milk, of food generally, the ripening of cheese, the decay of timber, and the putrefaction of all animal and vegetable matters. All these processes can be prevented by simply excluding the germs which are contained in the air, as is done in "canning" food, or by destroying their vitality by heat or antiseptics. When the biologist learns to detect in water "the specific poisons of zymotic diseases," and to distinguish them from the harmless organisms that we eat, drink, and breathe with impunity all our lives, then we may set up biological analysis as superior to chemical analysis, for the selection of drinking water.

Up to the present time, however, biological analysis will not tell us anything with regard to the Hudson River water that we do not already know. The river receives a small amount of drainage, and thanks to the oxygen and the micro-organisms, it becomes so thoroughly purified that, when it reaches the Bleecker reservoir for distribution in Albany, it may be drank without danger to health.

Some stress has been laid on the fact that nematoid worms were found in the mud taken from the basin near the mouth of a sewer. While it is not claimed that these worms were found in the water of the river, the only object in mentioning them was to associate them in some way with the water-supply. I would simply note that they are of no significance in any case, as nematoid worms are found in all fresh water, especially in ponds and lakes. They are also found in sour paste, and in vinegar, and are well known to microscopists as paste eels and vinegar eels.

Speaking again of the omnipresent organisms which are harmless to man, the *zymogenic organisms* which produce the fermentations—alcoholic, acid, viscous, etc.—and the *septic organisms* which produce putrefaction, it has been suggested that under certain extraordinary influences they may undergo some peculiar change by which they may develop into *pathogenic organisms*, capable of producing some specific germ and its zymotic disease.

This has actually been claimed in several cases, but it is clearly settled now that in no one of these cases was there any satisfactory evidence of such a change. The pathogenic organisms are distinct and peculiar, and are not in any way developed from the others.

III.—ADVANCES IN THE KNOWLEDGE OF ZYMOTIC DISEASES.

Since the biologists have perfected their methods for studying micro-organisms by the addition of new methods of staining, culture, and inoculation, the most wonderful advance has been made in the knowledge of zymotic diseases. The labors of Pasteur in investigating the diseases of silkworms, of Davaine, Koch, and Pasteur in investigating splenic fever, of Pasteur on chicken cholera, of Obermeyer and Carter on relapsing fever, of Pasteur on swine plague, of Koch on tuberculosis and cholera, and of these and other observers on many other diseases, have thrown a flood of light on the etiology of zymotic diseases. It would seem as if a few years would make the biologist master of the situation ; as though this class of diseases may perhaps be brought entirely under

the control of the physician, by a kind of preventive inoculation, as is now the case with smallpox.

But after all, this advance in knowledge has not as yet thrown any light on the question we have before us. Is the water of a large river, which has received a certain amount of drainage, a safe beverage for a city? Nothing in the discoveries of these great investigators enables us to say that this water is unsafe. It is believed that typhoid fever and diarrhœal diseases have often been disseminated by polluted wells, but no cases of these diseases have ever been traced to the waters of a large river.

The Cholera Question.

It having been established with some considerable degree of probability, that the wells in certain parts of London had aided in disseminating the cholera poison during the successive visitations of that disease to the metropolis, an opinion had gained credence that the water of the Thames had contributed in no small measure to swell the awful list of victims who died from that disease, especially the water supplied by the East London water-works. Considerable testimony was therefore taken upon this point by the Water Commission, the most important of which I will quote.

Testimony of Dr. Robert Angus Smith, Government Inspector.

"If the germs pass into the rivers we do not know how far they may be carried. On the other hand, we do not know that they ever can be carried in pure water, the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission, in otherwise pure water, is wanting. One might ask if a cholera germ in the water at Oxford would produce disease in London, and one might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know, but it seems probable that disease cannot be carried far by pure air, nor by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs, but the evidence seems to be that it requires an unusual excess to attack us successfully, it seems to be a question of quantity."

Testimony of Dr. Letheby, Medical Officer of Health to the Corporation of London.

Q. "You are aware that it has been alleged that the main cause of the cholera, in the east end of London, was due to he water-supply; do you entertain that opinion?" A. "No, I entertain the opposite opinion; it was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply; in the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connection with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease; I therefore investigated it very fully."

Q. "Do you think the present supply of water to the London people is wholesome water?" A. "I do, a thoroughly wholesome water."

In his report on the sanitary condition of the city of London for the years 1866–67, Dr. Letheby is much more explicit in his discussion of the cholera epidemic of 1866. He says, on page 26 *et seq.*:

"But difficult as the problem is, to determine the exact value of the several circumstances which influence the severity of the disease, and especially those which give to it its marked local intensities, enough has been ascertained to indicate its general habits, and to show that it fixes itself at low levels in proximity to tidal rivers, among dense populations, that are living in ill-constructed houses, that are filthy, badly ventilated, badly drained, and generally defective of sanitary provisions; and the inference is, that the actual agent of cholera, be it what it may, can only find congenial conditions for its full development in damp and impure air."

"The theory of Pettenkofer is, that the essential conditions for the active manifestations of the disease, are a porous soil, charged with excrementitious matter, and having a certain degree of hydration, as happens when the subsoil water has been just drawn off or is slowly retiring. All these conditions were singularly coincident with the localization of the disease in the eastern districts of London; for the soil is gravelly, and therefore very porous to air and water, and it is largely charged with excrementitious matters derived from the local tide-locked sewers. It is also remarkable that for some months before the outbreak of the disease, the subsoil water had been gradually sinking in consequence of

the drainage operations that were necessary for the construction of the main low-level sewer, and its branch to the Isle of Dogs. Now, according to Pettenkofer, it is exactly under these circumstances that a district is most liable to choleraic infection."

"The alleged pollution of the water rests upon a series of assumptions, many of which are in the highest degree improbable."

"Apart, however, from the improbabilities of these assumptions, it is a fact that the water which is said to have been thus polluted did not produce its effects in the several districts to which it was distributed in anything like uniformity of time or force. Suppose, by way of illustration, that alcohol or arsenic had become mixed with the water, and that on a certain day it was distributed to the public, we should expect to find that the action of the poison was not only manifested at the same time over the whole district of supply, but that it was confined to that district. Not so, however, with the water in question, for although it is not alleged to have been more than once polluted, yet the first effects in the several districts occurred at long intervals; and there were many places to which it was distributed, where there was no sign of the disease; while others, which did not receive the water, were seriously affected."

"More remarkable still, there were places in the very heart of the cholera field, and others close adjoining it, where the residents received the same suspected water, and used it freely without suffering in the least degree. In the Limehouse School, around which the cholera was frightfully fatal, there were 400 children who drank the same water as their neighbors, and yet there was not even a case of diarrhœa among them. In the London Hospital, which is also in the heart of the cholera field, for it is surrounded by the districts of Whitechapel, Bethnal Green, Mile End, Old Town, and St. George's-in-the-East, there was an average resident population of 463 persons, and, although they drank freely of the unfiltered East London water, yet there was not a case of illness among them."

"Again, in the eastern division of the city of London, which adjoins the cholera field, the suspected water was supplied to 161 houses, with a population of about 1,732 persons, but except in one of these houses (20 Somerset Street), which is on the boundary of Whitechapel, there was not a single death from cholera, and to verify this, I have obtained the addresses of all the persons who died in the cholera ward in Bishopsgate Street. But, besides this, the disease was singularly fatal in places where the suspected water was never used. In Crown Court, Blue Anchor Yard, Whitechapel, where the water-supply is from the New River, the mortality

was at the rate of 284 per 10,000. In Boar's Head Yard, of the same district, which is also supplied by the New River, the death-rate was 193 per 10,000 ; and indeed there are eighteen courts in Whitechapel, where none of the East London water was used, and yet out of an aggregate population of 4,351 persons, there were 30 deaths from cholera, the mortality being at the rate of 69 per 10,000 ; that of the whole district being but 77."

"So that, on carefully examining the facts in their relation to the water theory, we find :

1. "That there is no proof whatever of choleraic pollution of the water."

2. "That there was no coincidence of time in the appearance of the disease in the several districts supplied with the suspected water."

3. "That numerous districts receiving the same water, but situated at high level, or placed beyond the cholera field, were entirely exempt from the disease."

4. "That even in the very heart of the cholera field, there were places receiving and using the suspected water with impunity.

5. "That other places not supplied with the water, but situated within the infected area, suffered equally with the neighborhood."

"I am far from wishing it to be thought that choleraic matter diffused through water will not produce disease. There is abundant evidence to show that it is often a prolific source of it ; but I am anxious, in dealing with a question of so much public importance as the origin of the late epidemic, that none of the facts should be perverted, and that no hasty or ingenious hypothesis, without solid foundation, should take possession of the public mind. In the conduct of inquiries like this, there should be a calm, a full, and a candid examination of the facts ;—we should endeavor to study the phenomena in a philosophical spirit, and apply to them the tests of sound induction ; we should strive also to deduce from them such laws as will not only expose the nature of the malady, but will, at the same time, enable us to treat it successfully. Rash opinions, boldly asserted and tenaciously held, though they may force themselves on public attention, rarely lead to useful results ; and while they have their hold on the popular mind they seriously hinder the progress of real knowledge."

These extracts are sufficient to indicate the opinions of the most eminent medical officers who have considered the fitness of the waters of the Thames for supplying the people of London with wholesome water.

The verdict of the commissioners, after carefully and conscientiously weighing all the testimony presented, is as follows:

"The only point raised against the Thames water on the ground of organic contamination is of less positive character; it is said that water which has been once contaminated with sewage, may still contain undecomposed organic matter, which, though inappreciable by the most delicate chemical tests, may still exercise prejudicial effects on the human system."

"The strongest form of this objection has reference to some opinions now prevalent, that certain forms of disease, such as cholera and typhoid fever, are propagated by germs contained in excremental matter; and it is conceived possible that when matter of this kind once gets into streams, these germs may escape destruction and long preserve their dangerous character. It is said that no process is known by which such noxious material can be removed from water, and, therefore, it is argued, that water which has at any time been contaminated by sewage is henceforth unsuitable for domestic use. But we cannot admit them as sufficiently well established to form any conclusive argument for abandoning an otherwise unobjectionable source of water-supply; we are of opinion that there is no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome."

This report was made in 1869, and has been before the British public in an accessible form, in all its details, sixteen years, and its conclusions have been generally accepted.

Cholera in 1884.

A fresh opportunity was offered last year for studying the propagation and dissemination of cholera. Dr. Koch had succeeded in detecting peculiar comma bacilli in the intestines of persons who had died of cholera in Egypt and Calcutta; and he has satisfied himself that these bacilli are the true originators of the cholera. As he has been the most successful investigator of pathogenic bacteria, his opinion carries great weight. Nevertheless, there are many who are not yet convinced.

Dr. Koch noticed "that the cholera often settles in a particular locality, and displays its greatest virulence in certain quarters. Such epidemics are frequently observed in the sur-

roundings of the so-called 'tanks,' which are small ponds or wells enclosed within huts. The neighbors obtain their water-supply from these tanks, and simultaneously utilize them for various purposes—such as bathing, washing clothing, cleaning domestic utensils, etc."

In one of these tanks Dr. Koch discovered the comma bacillus, and thus found an argument in favor of the transmission of cholera by the water-supply. Not of a large river, to be sure, but by a "tank." A very animated discussion has arisen from these observations, and the cholera in the South of Europe last summer has furnished much material. The outbreaks in Toulon, Marseilles, Italy, Spain, and Paris have been very carefully studied, and thus far no evidence has been secured to connect the spread of the disease with the water-supply.

One writer says: "The microbists' theory of cholera propagation rests mainly on the hypothesis that water is the agent that spreads the disease. Now, Paris is supplied with water from four different sources, and the cholera broke out almost simultaneously in quarters the farthest removed from each other, and furnished with totally distinct water-supplies. It was predicted that those who drank the Seine water would be the chief sufferers, owing to the extent to which it is contaminated. The prediction has not been verified. The most virulent outbreak was in the charitable institution kept by the *sœurs hospitalières*, where over sixty inmates died in a few days. This home is supplied with the water of the Vanne —beyond all comparison the purest that is brought into Paris."

R. DeLuna says (in the *Compt. Rend.*, 97, 633): "The cause of cholera always exists in the air, and is transmitted by persons and things. It generally acts through the organs of respiration, and incubation generally takes place when the individual is in a passive condition, and particularly during sleep."

M. Gibert, in describing, in the *Revue Scientifique*, the outbreak of cholera at Yport, near Havre, says: "The cholera was brought to Yport by insufficiently disinfected clothing, soiled by cholera dejecta; that the disease was propagated from house to house; and that the question of water has no bearing in the case, for the very good reason that the Yportais never drink any."

In a long article on "Cholera," which runs through several numbers of the *London Lancet* in November, 1884, Dr.

Max von Pettenkofer, of Munich, the leading sanitary authority in the world, makes the following statement :

"The further one investigates the drinking-water theory the more and more improbable does it appear. Robert Koch, too, the famous bacteriologist, has hitherto failed to substantiate the drinking-water theory, and I feel convinced that the time is not far distant when he will own that he has gone in the wrong direction. Koch has succeeded in finding the comma bacillus in a water-tank in a region where cholera was prevalent. I have the greatest respect for this important discovery, not as a solution of the cholera question, but only as a very promising field for pathological, not epidemiological, inquiry. It must be remembered that cholera was already prevalent in the neighborhood of the water-tank from which Koch obtained the bacillus. Now, this tank was used not only for drinking purposes, but also for bathing the person and washing clothes, as Koch himself admits. According to my view the comma bacillus must have been present in the water. It had not been shown, however, that the bacillus was in the water before the outbreak of cholera. Koch is of the opinion that all the bacilli in the water-tank could not have come from the washing of clothes of cholera patients, but must have partly been derived from multiplication, yet he forgets that, as he himself has shown, the meat-broth in which the bacilli grow must not be too dilute. It would have been interesting if Koch had estimated the strength of the nutritive material in the water-tank. But what chiefly contradicts the doctrines of the contagionists is the simultaneous disappearance of the cholera on land and the cholera bacillus in the water-tank. If it were really true that every case of cholera, the first as well as the last in an epidemic, had the same infective material in its intestinal discharge, and that the epidemic only ceased because the susceptibility of man had passed away, then the bacillus would continue to exist in the tank, always supposing that there was sufficient pabulum for it. And thus it is most probable that the bacillus gets into the tank from man, and not *vice versâ*. While Koch was in Calcutta the English physicians there imbued him with their views on cholera and drinking-water. The English had been brought up on the drinking-water theory of typhoid fever and cholera, and could only lay it aside with difficulty. But a few of those English physicians who had studied widespread epidemics had renounced their original ideas. Dr. Bryden (the chief of the Statistical Department), Dr. J. M. Cuningham (the Sanitary Commissioner), Dr. John Macpherson (the Inspector-General of the Bengal Army), Dr. Lewis, and Dr. Douglas Cunningham, were all disbelievers in the drinking-water theory."

I quote these opinions not because I entertain them all myself, but to show that the best authorities do not sustain the theories or the fears that have been expressed by the opponents of the river water at Albany. I believe that wells and small streams may be so polluted as to disseminate disease.

IV. THE TEST OF EXPERIENCE.

When, in 1872, I first had occasion to consider the question of employing the Hudson River water at the city of Albany, I was limited in my study to the chemical examination of the water by the methods then in use, and to the careful comparison of the size of the water-shed of the Hudson River and the populations residing thereon, with the water-sheds and population of other large rivers used successfully as a source of water supply. My conclusion in favor of the use of the water at that time was arrived at with a full appreciation of the great responsibilities of the decision.

In the following spring I was placed at the head of the Health Department of the largest city in this country, and for eleven years a large part of my thought and study was directed to sanitary questions. I found myself compelled to study every subject bearing upon the public health, and I have never lost sight of the important issues involved in my decision of the Albany water question. I have from time to time made inquiries with regard to the health of the citizens who were using the water of the Hudson River, and it has always been a source of great satisfaction to me to learn that the health of the people of Albany continued to be remarkably good, and that no evidence was presented to indicate that the use of this water had resulted in any ill effects, and I have never had occasion to regret the advice I gave at that time. The diseases which have been attributed to polluted water are especially typhoid fever and diarrhœal diseases, with which the city of Albany has been less afflicted than most other large cities in this country, many of which are supplied with water of the highest degree of purity. I am satisfied, therefore, that the test of experience fails to present any facts which would indicate that the Hudson River water is unwholesome.

The following Tables XII and XIII present the deaths

from these diseases in Albany and the towns above, and also for further comparison, New York City, Brooklyn, and Rochester. The figures were obtained from the last four *Bulletins* of the New York State Board of Health—the only ones to which I had access. As the city of Troy receives the Hudson River water from above Lansingburg, it would naturally be inferred that if the water becomes polluted through its passage past the city of Troy there would be an increase in the death-rate of the city of Albany from the diseases attributed to polluted water. It will be observed that this is not the case, but, on the contrary, the returns from the city of Troy indicate a much larger death-rate from these diseases. It may be said that these returns are not complete. This is no doubt true. A note at the foot of the November *Bulletin* of the State Board of Health remarks that, "The returns from several localities, Troy especially, are notably incomplete," and a note to the December *Bulletin* says, "In Troy the actual burials for November were found on investigation to be 146, but 43 having been reported; the December returns show improvement, but are still incomplete. Returns from Cohoes are utterly unreliable and are now under investigation by this Board." It would appear, therefore, that the incompleteness is particularly in the Troy returns, and that if the full death-rate were recorded the contrast between Troy and Albany would be much more striking, the Albany returns being considered the most reliable of them all.

In Table XIII the death-rates per 1,000 per annum are presented, computed from the numbers contained in Table XII. It will be noticed that in the fourth column the typhoid fever and malarial diseases have been added together. This is done because it is well known to every physician who has had occasion to investigate deaths attributed to malaria, that in the majority of cases the deaths were really due to typhoid fever. These figures clearly show that there is nothing in the vital statistics of Albany to indicate that any evil result has ever followed the introduction of river water.

XII. Deaths from Typhoid Fever, Malarial and Diarrhœal Diseases, for the last Four Months of 1884.

Extracted from the Monthly Bulletins of the State Board of Health of New York.

	Deaths.	Rate per 1,000.	Typhoid.	Malarial.	Diarrhœal
ALBANY—Population 97,344.					
September	153	18.86	8	2	23
October	148	18.25	3	0	8
November	141	17.39	5	0	4
December	146	18.00	1	1	3
Four months	588	18.12	17	3	38
TROY—Population 60,000.					
September	130	26.00	7	0	25
October	70	14.00	4	1	4
November	43	8.60	3	1	1
December	81	16.20	1	0	1
Four months	324	16.45	15	2	31
WEST TROY—Population 13,000.					
September	26	24.00	3	0	5
October	17	15.69	2	0	3
November	20	18.46	0	0	0
December	26	24.00	2	0	1
Four months	89	20.54	7	0	9
LANSINGBURG—Population 8,500.					
September	22	31.00	0	0	2
October	27	38.11	0	0	0
November	21	29.64	0	0	0
December	25	35.30	0	0	0
Four months	95	33.74	0	0	2
COHOES—Population 20,000.					
September	15	9.00	1	0	3
October	7	4.20	0	1	0
November	12	7.20	0	0	1
December	21	12.60	1	0	0
Four months	55	8.25	2	1	4
GREEN ISLAND—Population 5,000.					
September	5	12.00	1	0	0
October	6	14.50	0	0	0
November	6	14.50	0	0	0
December	7	16.80	1	0	1
Four months	24	14.37	2	0	1
NEW YORK CITY—Population 1,356,958.					
September	2,980	26.45	62	34	540
October	2,543	22.48	66	57	301
November	2,807	24.82	54	39	95
December	2,987	26.42	35	23	45
Four months	11,317	25.04	217	153	981
BROOKLYN—Population 644,526.					
September	1,369	25.49	19	33	339
October	1,181	21.99	19	41	149
November	1,066	19.83	13	32	31
December	1,253	23.33	8	29	14
Four months	4,869	22.66	59	135	533
ROCHESTER—Population 101,000.					
September	181	21.50	4	0	42
October	146	17.35	7	0	18
November	135	16.04	9	2	1
December	137	16.27	9	0	3
Four months	599	17.79	29	2	64

XIII. Death-rates per 1,000 per Annum for the last Four Months of 1884.

Computed from the Data Contained in Table XII.

	Deaths from all causes.	Typhoid fever.	Malarial diseases.	Typhoid fever and malarial diseases.	Diarrhœal diseases.
Albany	18.12	0.525	0.090	0.615	1.173
Troy	16.45	0.750	0.099	0.849	1.548
West Troy	20.54	1.620	.....	1.620	2.070
Lansingburg	33.74	.....	.....	.....	0.708
Cohoes	8.25	0.300	0.150	0.450	0.600
Green Island	14.37	1.200	....	1.200	0.600
New York	25.04	0.480	0.339	0.819	2.169
Brooklyn	22.66	0.270	0.630	0.900	2.484
Rochester	17.79	0.861	0.060	0.921	1.899

CONCLUSION.

After applying every possible method of investigation to the Hudson River water, I am free to say that I find no evidence to lead me to change the opinion I expressed in 1872. There is no reason why the city of Albany should not continue to use this water.

Except at Troy, no sewerage of any consequence is discharged into the river; and even here, the volume of sewerage is so small in comparison with that of the river, that it does not make any impression upon it.

The average volume of the Hudson at Albany was estimated by Mr. Sweet to be 618,111 cubic feet per minute, equal to an average daily flow of 6,677,000,000 gallons. The minimum being 1,829,000,000 in July, and the maximum 12,330,000,000 in March.

In 1883, the engines pumped an average of 6,064,000 gallons daily, or $\frac{1}{1100}$ of the average flow of the stream.

I must not omit to call attention to the unusual combination of circumstances by which the most complete aëration of the water is effected. Glens Falls, the falls of the Mohawk at Cohoes, and the State Dam at Troy, are the most effective means contrived by nature and art for preparing the water for the use of your citizens.

1. Chemical analysis shows that the water compares favorably with that of other cities in this country and Europe.

2. Biological analysis reveals nothing in the water that has ever been known to produce sickness.

3. Culture experiments have failed to connect in any way the omnipresent organisms which are found in all waters with any diseases, or to make it probable that they are likely to produce any evil effects. The experience gained during the recent outbreaks of cholera in the East and in Europe have added nothing to the knowledge of this disease that makes it probable that, in case we have an invasion of it next summer, the river water would be likely to aid in introducing it into your city.

4. Experience in using the water for the past ten years has demonstrated its freedom from objectionable constituents. There have been no epidemics during that time, and the city has been less afflicted with the diseases which are generally supposed to spring from polluted water, than Troy and other towns, that take the water above that city ; or than New York or Brooklyn, which are supplied with unusually pure water.

5. With regard to the pollution of the water-supply by the action of the tide on the water which flows out of the Basin, I can only say that if anything is added to the water from this source it must be extremely small in quantity. Several of my samples were taken from the river at the inlet, half at low tide and half at high tide, and several were taken from Bleecker reservoir. None of these samples show the presence of such contamination, and they could not have failed to do so, had there been any to show. Although there is no appreciable contamination from this source, I would nevertheless strongly urge the adoption of the recommendation of the Committee on Drainage and Topography of the State Board of Health with regard to cleaning out the Basin or filling it, and also the construction of an intercepting sewer.

6. I would also advise that steps be taken to protect Tivoli Lake from drainage waters, which now find their way into it to some extent.

7. I would further say that I consider the water of the river so free from any objectionable contamination, that the whole question seems to me to be one of practical economy for the taxpayers. If there were an equally available supply of water from a source against which no one, however biased, could sug-

gest a suspicion (I know of no city that has a supply of water which does not at times arouse the alarmists), then I would say, as a matter of sentiment, to silence if possible all complaints and arguments, abandon the river. But it would be very foolish to abandon a never-failing supply of wholesome water, which can be had by simply pumping, to go to large expense, simply as a matter of sentiment, to prevent a few persons from saying disagreeable things about the quality of the water. Besides, if water were brought from some lake, a new class of troubles would result. Lakes are very liable to be invaded, at certain seasons of the year, by abundant growths of vegetable or animal matter, which communicate color, taste, and odor to the water which are very offensive. Almost every city in the country that is supplied by lake water has experienced this difficulty.

In studying this subject (to use the language of Dr. Letheby, already quoted), I have been "anxious, in dealing with a question of so much public importance, that none of the facts should be perverted, and that no hasty or ingenious hypothesis, without solid foundation, should take possession of the public mind. In the conduct of inquiries like this, there should be a calm, a full, and a candid examination of the facts ;—we should endeavor to study the phenomena in a philosophical spirit, and apply to them the tests of sound induction. Rash opinions, boldly asserted and tenaciously held, though they may force themselves on public attention, rarely lead to useful results ; and while they have their hold on the popular mind they seriously hinder the progress of real knowledge."

Very respectfully yours,

C. F. CHANDLER.